TEAC®

White Paper on Tape Technology

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FRIENDS, THE HONEYMOON IS OVER.

There was a time when most of the persons buying audio components were making their first purchases and their ignorance was as great as their bliss. Somewhere along the way, almost all of them got burned on one component or another - and the romance ended. The product may have been worth what it cost; but out-of-context specifications, and advertising campaigns based on superlatives, built the expectation higher than the reality could reach.

MOST HONEYMOONS END THAT WAY.

Now most of those persons are working on their second or even third system, and they are going to consider TEAC. We are going to consider them. We are taking a position unique in audio, as far as we know. We insist that:

1. The customer is possessed of intelligence. That if manufacturers and retailers provide him with information, he can and will understand it. He can and will make a purchase with which he will be pleased.
2. The retailer is possessed of intelligence. That if manufacturers provide him with information, he can and will take the time and effort to assimilate it and pass it on — recognizing the manifold benefits of a happy customer.

Granted, there will always be the "pie in the sky" buyer, and piemakers who will promise it to him. But in the course of things, there comes a time when someone — an individual or an entire organization — recognizes that its economic world has passed a watershed, and change is the order of the day. The audio industry has passed such a watershed. Now both equipment and buyer are far too sophisticated for puff and hype. The time has come for leveling. The time has come for our industry to teach, to find new ways of educating the new consumer. The White Paper is our beginning. It tells about us: TEAC CORPORATION OF AMERICA.

CORPORATE PHILOSOPHY

When we started, this paper was a fairly straight-forward project. We wanted to devise a way for a person who was neither an engineer nor an audiophile to make some reasoned judgments about our tape recorders. We were going to tell you how our metering system works, how our transports are designed, how our specifications are derived, and the like.

However, we discovered that we were raising more questions than we answered: How can you evaluate the worth of *our* metering system until you understand others, how *are* transports designed, what specifications are important, anyway?

Finally, we decided to tell you about us, our attitudes toward our products, and our philosophy in designing them. We also will tell you as fairly and clearly as possible about attitudes and philosophies which other manufacturers have chosen. For the most part, they believe in them as strongly as we believe in ours.

However, we say that TEAC is "The Leader. Always has been". We firmly believe this too. But unless we publicly state our attitudes and philosophies, we can only hope that you will accept them; we have no right to expect that you will.

HEREWITH, OUR PUBLIC STATEMENT.

A philosophy is a **series** of decisions, usually proposed as solutions to crucial issues or problems. Every design effort, from automobiles to tape recorders, is a series of decisions about alternatives - to gain one desirable item, another usually must be sacrificed. For example, an automobile may have a soft, floatingly comfortable ride, but usually this is at the expense of agile, positive handling. It may have enormous power, but usually at the expense of fuel economy.

This is purely a matter of design and marketing philosophy. The same technology is available to both Porsche and General Motors, but the design and marketing philosophies are significantly different. We believe that neither is intrinsically right or wrong — that decision is entirely the province of the purchaser. Different strokes for different folks.

The same is true in tape recorders. There are no secrets to design: the principles are known to any competent engineer. The differences you see in the products on an audio retailer's shelf lie in the alternatives chosen at each design and marketing decision point. For example, as you will see later, one unit may have greatly extended high frequency response; but achieved only at the expense of added noise (tape hiss).

Because of some very basic design decisions we have made at TEAC, our products cost a lot of money. But they are not "expensive". To us, an expensive product is one which costs more than it should. No TEAC product has ever been expensive; none ever will be. We call ourselves "The Leader" because more persons buy products in our price category from us than from any other company in the world. We say "Always has been," because we've been building products like these for over 20 years, longer than anybody else.

The persons who design and build our products are craftsmen; and a craftsman is a person who builds something better than it has to be. They feel that the pride in owning a TEAC is almost as great as the pride in building one. They come up with design innovations years ahead of the current state of the art, and most of them will never see the light of day. Because at this point, the craftsman attitude comes into play.

Before they will put them into production, they build lots of prototypes and use them, abuse them, do their best to make them break. Each time they succeed, they refine. Break and refine, again and again. Until it doesn't break anymore.

By this time, another company may have developed the same innovation, but the tyranny of the profit motive put it into production immediately: field testing is thus often done by consumers.

TEAC, on the other hand, maintains recording studios in both Los Angeles and Tokyo. In Los Angeles we also retain a large group of professional musicians, record producers and recording engineers, whose sole purpose at TEAC is to beat up our new products and tell us what's wrong with them. By the time we're satisfied, and they're satisfied, we know you will be. At TEAC, field testing is done by **us.**

Each of our products is fully tested for quality control. It is then packed, and shipped. Then it is opened and fully tested again. Then, and only then, is it finally shipped to a TEAC dealer. Every product.

Because of all this, when you buy a TEAC, you don't just buy a product; you buy a piece of the company. And we are able to guarantee each of our products for two years, both parts **and** labor. That doesn't mean just mechanical and electronic function: It means performance as well - all original specifications will be met. No exceptions, no caveats, no hassle: Two years, parts **and** labor.

We know it will **work** when you get it, and keep on working. And in these days of plastic disposable everything, we think that the pride our craftsmen take in that knowledge is justifiable.

TEAC WHITE PAPER ON TAPE TECHNOLOGY

If it's true that "a little knowledge is a dangerous thing," then many tape recorder owners and prospective owners are in danger. But it isn't their fault; there simply is a conspicuous lack of adequate information on tape recorder theory. Most books on the subject do not relate modern innovations in tape, electronics, and mechanics to theoretical first principles.

This doesn't mean lack of information on tape recorders **per se.** Reams of spec sheets detail the "what" and "how" of tape recorders. Few tell the "why". As a result, most consumers rely on specification sheets to determine the best recorder for their needs. Unfortunately, specification sheets don't truly describe the total performance that a tape recorder can deliver.

This problem becomes clearer if we momentarily relate the tape recorder to other pieces of audio equipment. Generally, the prospective buyer interprets a tape recorder specification sheet as he would that of an amplifier. He'll study frequency response figures, power output and signal-to-noise ratios as if they were as easily quantifiable as size or weight. The catch in this type of comparison is that the amplifier is all electronic; but the tape recorder is an interrelation of electronic, magnetic, and mechanical systems.

Interestingly enough, a more closely related piece of audio equipment is the loudspeaker. The loudspeaker takes an **electrical** signal, converts it to a **magnetic** field; and this, in turn, drives a **mechanical** cone. During the last decade, audiophiles have come to realize that a speaker can never be judged solely by its specification sheet. It must be **listened** to in order to fully determine its quality.

However, performance of both speakers and tape recorders can be adjusted and frequency response curves accentuated or bumped at both low and high ends to give the illusion of "high" fidelity (see Figure #1).

Both tape recorders, represented by the solid or the dotted lines would show the same response specification of around 30 to 18 kHz ±3dB. The recorder represented by the dotted line might sound "better" because of the bumps at 50 and 10 kHz. The solid line represents the professional "flat" curve that TEAC strives to achieve.

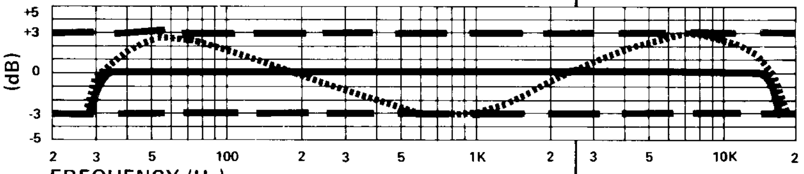


FIGURE 1

Sometimes even high distortion or high frequency hiss can also fool the listener into thinking that a particular unit has superior frequency response.

There are many other choices in tape recorder design that can mislead the customer. Partially, at any rate, this stems from the fact that much of tape recorder design involves compromises. Not compromise of quality, necessarily. Rather, it is the recognition that to achieve a specific result, other parameters often have to be less than optimum. For instance, if a manufacturer wanted to be able to publish astonishingly high frequency response figures, he could do so. But only by compromising other desirable conditions, such as high signal-to-noise ratio and minimal high frequency hiss or distortion.

What emerges here are the following principles: first, tape recorder design largely involves seeking a proper and harmonious balance between desired parameters. High frequency response vs. increased hiss is just one of them. Second, the philosophy of the manufacturer is crucial to competent evaluation of competing products. Let's face it. Tape recorders in the

TEAC price category are both sophisticated and quite well made. The often ambiguous spec figures and colorful superlatives are no longer sufficient nor fair to the prospective customer who needs — deserves — all the background information he can get before trusting us with anywhere from $300 to $3,000 of his money.

The Magnetic Personality of Tape

Since the unique aspect of a magnetic tape recorder is the magnetic system itself, let's take that one on first.

The magnetic system is made up of two components: (1) recording tape, and (2) the heads, for erasing, recording and playback. Tape consists of two layers: (1) a base material, generally an acetate or a polyester, and (2) an oxide coating of binding resin and either ferric oxide or chromium dioxide particles immersed in the binder. These oxide particles are the "live" part of the tape. They have the ability to become easily magnetized when an external magnetic field is applied to them.

This external field is generated by a record head that functions like an electro-magnet. When an alternating current is sent into the record head, it generates a magnetic field. Like any magnetic field, this one has north and south polarity. When it comes in contact with the oxide particles on the moving tape, the field magnetizes them in one direction on the other. (see Figure #2).

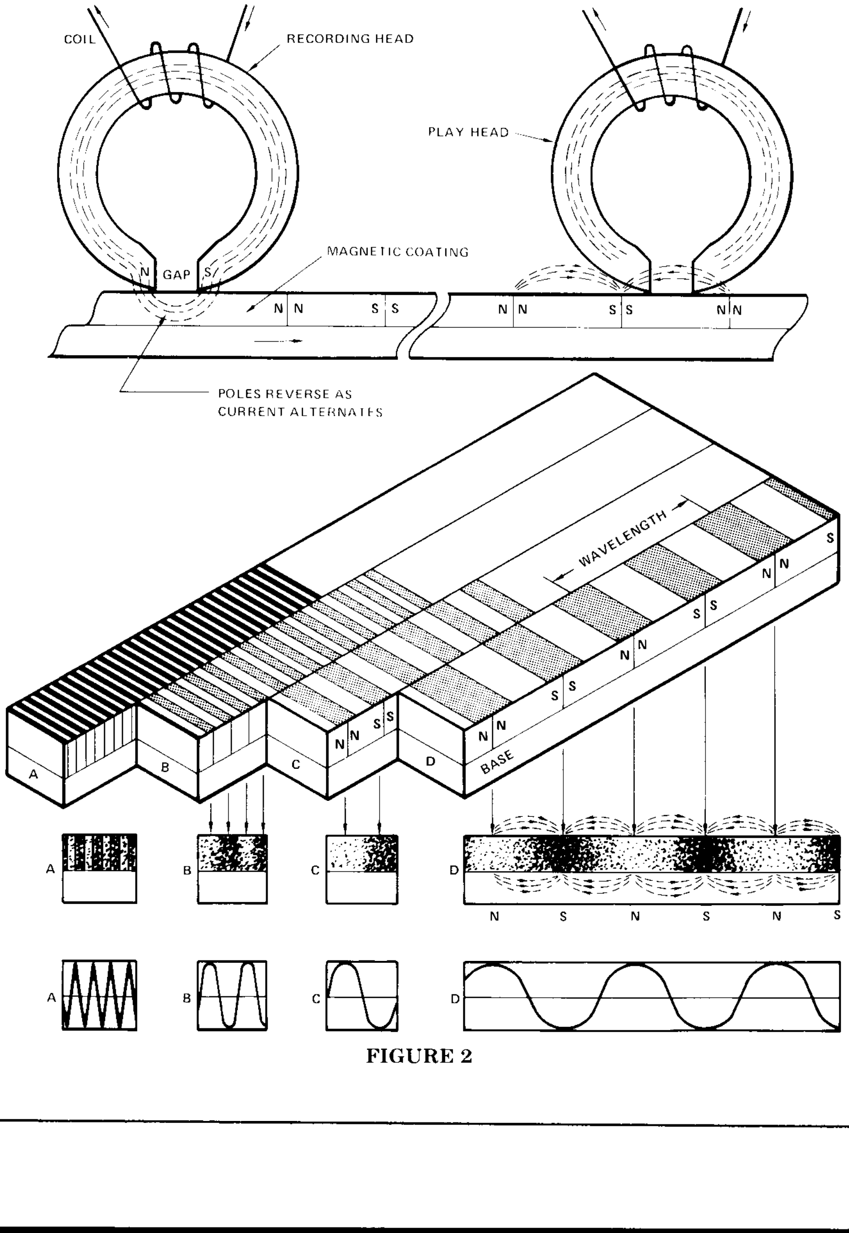


FIGURE 2

This creates a series of magnetic patterns on the tape that correspond to the various frequencies sent to it by the head. The higher the frequency, the shorter the magnetic field length. The lower the frequency, the longer the magnetic field length. Figure #2 shows four different frequencies (A, B, C, D) creating magnetic fields of different lengths. A complex signal, such as that of a symphony orchestra, will create a series of magnetic patterns of varying lengths.

When these magnetic fields on the tape come into contact with the playback head, a reverse process takes place. They induce magnetic flux lines in the playback head, generating a voltage which is then amplified and sent to the speakers.

Head Gaps and Frequency Response

The length of the playback head gap is one of the limiting factors affecting high frequency response in tape decks (see Figure #3).

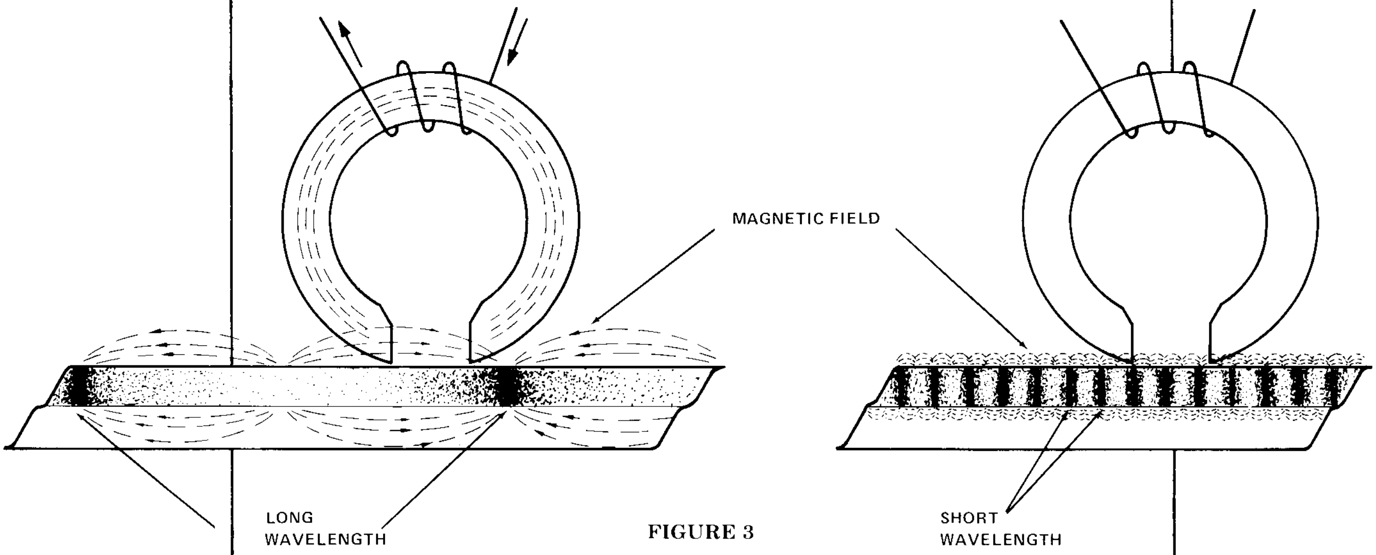


FIGURE 3

The shorter the wave length of a sound, the higher the frequency. When the wave length on the tape becomes so short that it equals the gap length of the playback head, the head can generate no more voltage. It would seem that the answer is clear: make all gaps smaller than the shortest wave-length in the audio spectrum. However, here enters the first design decision point!

For instance, a 15,000 Hertz (cycles per second) tone generates 30,000 separate magnetic fields imprinted on the tape. The length of one wave (a cycle) equals two magnetic fields (one field generated by the positive swing of the tone, and the other field by the negative). If the speed is 15 ips and the frequency is 15,000 Hz, the wave length is 15/15,000 or 1/1,000 of an inch.

In lengths this small, the unit of measurement used is the **micron.** One micron equals about 0.00004 of an inch. Therefore, the wave length of a 15,000 Hz tone recorded at 15 ips is 0.001 inches or 25 microns. But wave length on the tape is also determined by the speed of tape travel. At 7½ ips, the wave length of this same 15,000 Hz tone is reduced to 12.5 microns. At 3-3/4 ips, it drops to 6.25 microns. At 1-7/8 ips it's 3.13 microns. Thus, the wave length shortens as the speed decreases (see Figure #4). In other words, the wave length of a 15,000 Hz tone at 1-7/8 ips is the same length as a 60,000 Hz tone at 7½ ips!

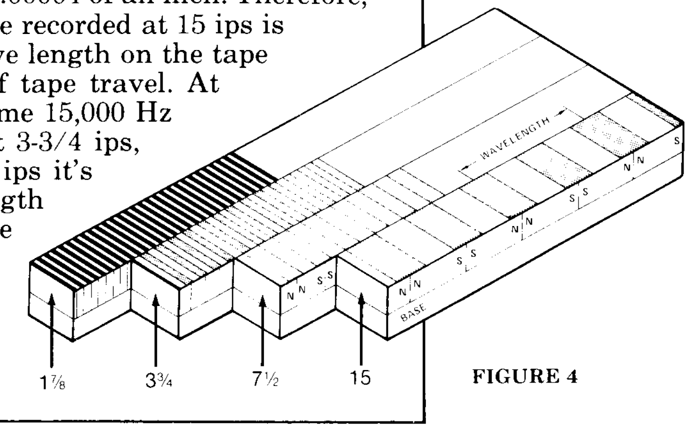


FIGURE 4

A question often asked is: If we can design cassette decks that will reproduce up to 15,000 Hz at 1-7/8 ips, why don't we design reel-to-reel decks that will reproduce up to 60,000 Hz? With that frequency response range, a reel-to-reel deck at 7½ ips would be able to directly tape record the CD-4 records that require response up to 45,000 Hz. Of course, few, if any, reel-to-reel machines deliver this kind of response. The fact that they don't leads us to realize that there must be factors that go into designing good tape recorders other than just high frequency response for its own sake.

All of this is leading to delineation of another principle: the interrelationship of reproduce head gap and efficiency. Remember, shortening the reproduce head gap allows that head to pick up high frequencies. Unfortunately, the narrower gap is less efficient. For example, when the gap is reduced from 4 microns down to 1 micron, the voltage output drops to 25% of the original — or a reduction of 12 dB. But to reproduce a 15,000 Hz tone at 1-7/8 ips, the playback head **must** have a very small gap (around 1 micron).

Obviously, the signal must have greater amplification to equal the level obtained with the 4 micron gap. But more amplification means more hiss. Some solutions: quieter electronics, noise-reduction circuitry, or modifications of other design parameters of the head.

But all these methods could have been utilized on the 4 micron gap to improve the signal-to-noise ratio of that unit. Why weren't they? Again, it is an issue of harmonious balance. With the wider gap permitted by high speed reel-to-reel machines(15, 7½ ips), the inherent low signal-to-noise ratios on better decks are generally enough to obviate the use of additional noise lowering features, and allow the money to be spent elsewhere improving some other aspect of the product's design.

Therefore, the professional method of choosing the proper gap width is first to decide for what speed the recorder is to be ideally designed. Then select a gap that will reproduce the entire audio spectrum (or as much as is practical), and still maximize the efficiency of the head for good signal-to-noise ratio.

There is, however, no choice of speed for cassettes; it has to be 1-7/8 ips. As a result, low noise capabilities must be designed around this slower speed. Reel-to-reel, of course, can be 3-3/4, 7½, or 15 ips. TEAC has chosen basically to design all reel-to-reel recorders for 7½ or 15 ips.

Of course, we offer 3-3/4 ips on some models, but it is essentially a compromise speed. Unfortunately, the current method of specifying performance on paper does not cause these differences and compromises to show up. Because when you see tape deck frequency response numbers or curves, the **level** at which these curves were recorded is seldom shown. Cassette curves are measured at levels of -20 dB or lower. Most reel-to-reel manufacturers also show their 3-3/4 ips curves at these levels. Obviously, one of the reasons curves are shown at these levels is that if they were recorded at -10 dB (the traditional reel-to-reel level), suddenly the cassette and 3-3/4 speeds wouldn't look so good. (See Figure #5.)

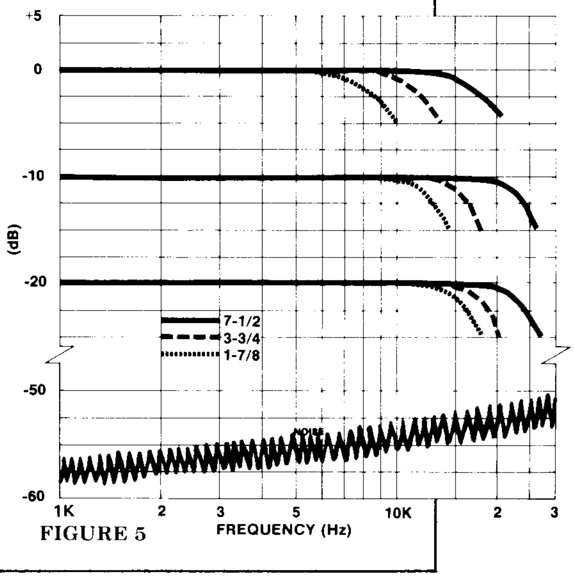


FIGURE 5

Some justification can be made for testing frequency response at -20 dB. Classical or mood music — recorded with a conventional acoustic orchestra — does not project at the same volume level across the entire audio spectrum (see Figure #6). Here, assuming typical mike placement, frequencies above 3 - 5,000 Hz should begin taking their normal roll-off (see Figure #6, Curve "C"). By the time frequencies reach 15,000 Hz they would be down over 20 dB in comparison to the loudest mid-range sounds. In this circumstance, the music could be recorded at normal recording levels at 3-3/4 or 1-7/8 ips without high frequency losses caused by tape saturation.

The problems arise with contemporary multitrack recordings, with their extremely close mike placement, electronic amplification, heavy equalization in the mixing console, and use of electronic synthesized sounds. As Figure #6, Curve "B" indicates, high frequency harmonics become progressively louder.

Obviously, the worst possible condition would occur when the source material contains high frequency material (above 10,000 Hz) at the same volume level as mid-range frequencies (see Figure #6, Curve "A"). Here the slow speed recordist (1-7/8 or 3-3/4 ips) will suffer high frequency losses if he allows his meters to deflect to normal levels. It means that he will have to back off on the recording level, which will hurt his signal-to-noise ratio. The amount of this level reduction depends on the listening preference of the user and is part of the creative and artistic aspect of tape recording. At TEAC, we think the user should have the option of deciding how much high frequency response he wants to retain at the sacrifice of optimum signal-to-noise ratio. Many manufacturers do not permit any leeway. But, more on this later.

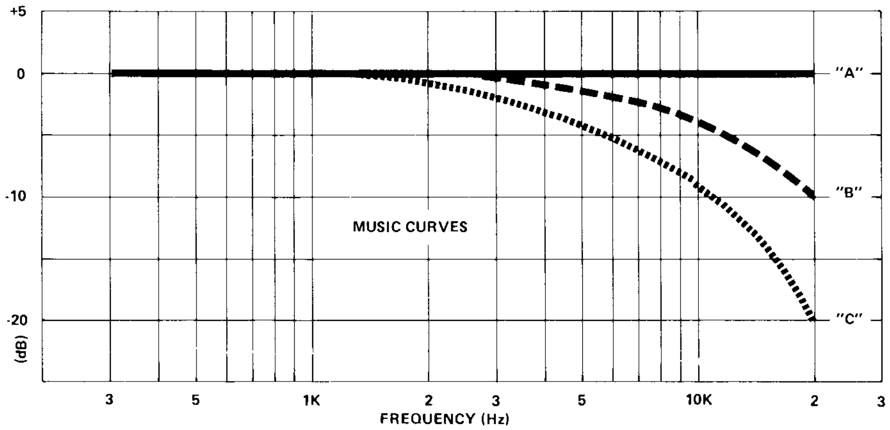


FIGURE 6

Remember, as the recording level is reduced, it gets closer and closer to the inherent noise or hiss of the recorder (see Figure #5). For instance, if the recordist seeks to maintain the widest frequency response possible at a speed of 3-3/4 ips, and the music contains frequencies of equal volume levels out to 20,000 Hz, the recordist would have to record at a level of -17 to -20 dB. If the published signal-to-noise ratio was 56 dB, the **effective** signal-to-noise ratio would only be 36 to 39 dB. Obviously, this would be the most severe test, but the real point in this: as music increases in level at the high end of the spectrum, then the slow-speed recordist has to make drastic compromises.

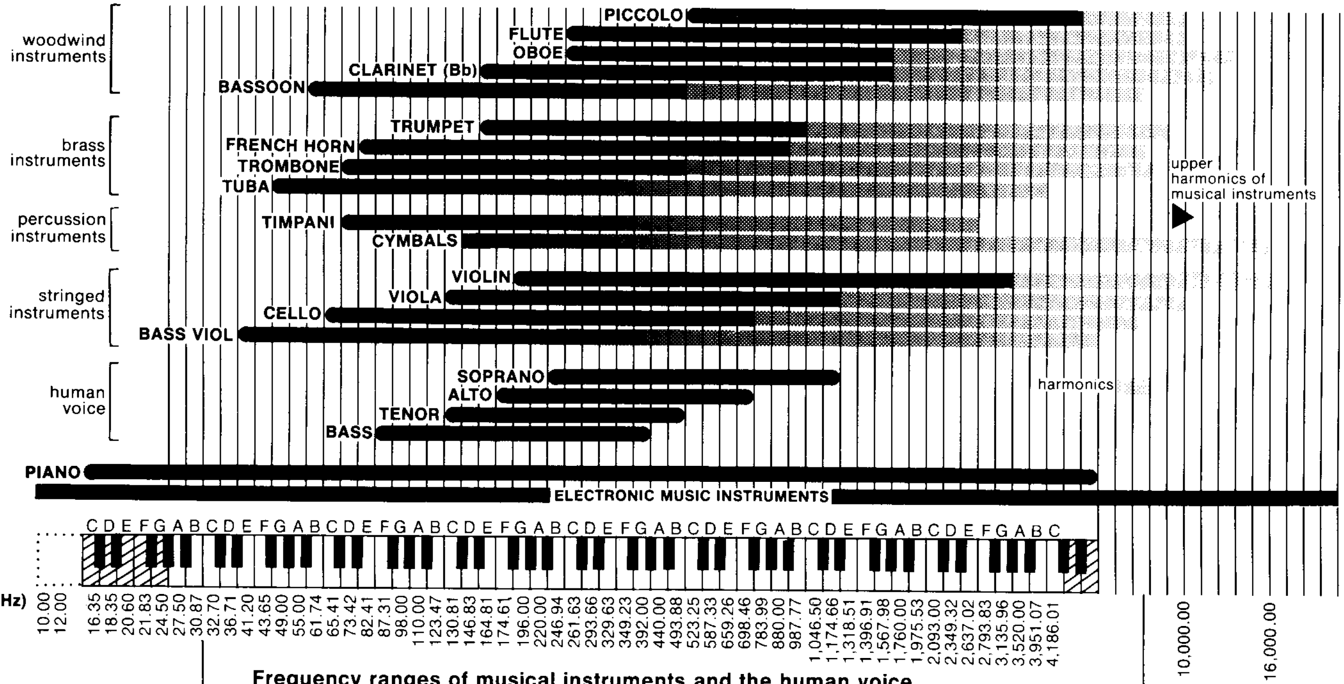
It would be unusual to increase mid-range hiss 10 to 20 dB to achieve a response in high frequencies that the normal human ear does not hear nearly as well (if at all) as it hears mid-range frequencies.

TEAC feels that this balance between frequency response and optimum signal-to-noise ratio must rest with the user. Some may want wide response with some hiss; others, less response and less hiss.

The design philosophy of many manufacturers always maximizes frequency response at the expense of signal-to-noise. They accomplish this through an equalized metering system. This system measures the signal level **after** the record equalization circuit has already boosted the high frequencies. Allowing the meters to read after record equalization forces the recordist to use lower and lower volume levels. For instance, with music that was flat across the entire frequency spectrum, the bulk of music in the mid-range is actually being recorded at -20 dB for 1-7/8, -17 dB for 3-3/4 ips. Therefore, the **effective** signal-to-noise ratio has been cut significantly.

Justification that equalized metering system proponents use is that when high frequency saturation occurs, you not only lose high frequency response — but you also get more high frequency distortion. This is true. However, one should never lose sight of the overall quality of the recording by looking at just a single aspect of it. To reduce high frequency distortion at frequencies close to the limit of audibility by utilizing an extreme decrease in overall level is a very dubious approach, since this results in a marked increase in audible, mid-range hiss.

Again, TEAC feels that this trade-off should be left to the final user and that no philosophical judgment should be dictated by the manufacturer.



Frequency ranges of musical instruments and the human voice.

Another problem generated by equalized metering occurs when different types of music are recorded on the same tape. If the music contains variations in high frequency volume levels from selection to selection, the result will be a disconcerting level difference in playback. The listener would find himself continuously adjusting his amplifier volume control to compensate for variations in average perceived loudness from selection to selection, if he had set his meter levels at the same position with each tune.

OF COURSE, THE SOLUTION TO ALL THESE PROBLEMS IS SIMPLY TO RECORD AT A FASTER SPEED.

As mentioned earlier, with state-of-the-art blank tape, you can record the entire audio spectrum without frequency loss at the normal "O" VU level, using 7½ or 15 ips (see Figure #5). All types of music, regardless of high frequency volume levels, could then be recorded at the **same** overall loudness. **That** is one of the reasons that professional recording studios still employ speeds of 15 and even 30 ips.

Never compromise performance just to save tape. A recordist invests a lot of money in his equipment, and a lot of time in recording with it. A lot of that is wasted, not on a theoretical level, but an entirely audible level,if he uses a slow speed. No matter how specifications are jockeyed, 3-3/4 ips is a compromise speed - and, for that matter, so is 7½ ips, compared to 15 ips.

Use the fastest speed you can; we'd like to see everyone using 15 ips. If you need more recording time, use 10½ reels and/or thinner tape. The point is, if you have a 7½/15 ips machine, you have the choice between economy and performance.

Measuring with Meters

Tape recorder metering systems are sensitive devices designed to help the recordist maximize level and minimize noise and distortion. However, more than one type of metering system is used today. To get the most out of the help they have to offer, a good understanding of their design and calibration is a necessity.

One of the standard methods of adjusting a meter for maximum level the tape can handle uses a 1,000 Hz tone fed into a recorder until the signal from the play head reaches 3% distortion (see Figure #7). This point is called "O dB", and all metering systems work from this level. A new method of specifying maximum level measures magnetic field strength on the tape. Its density is then expressed in "Webers". For the purpose of this discussion, however, it doesn't make any difference which system is used.

Music not only contains different frequencies at different levels, but it also contains levels that increase in intensity so rapidly that this level difference can only be measured in frac-

TAPE DYNAMIC RANGE

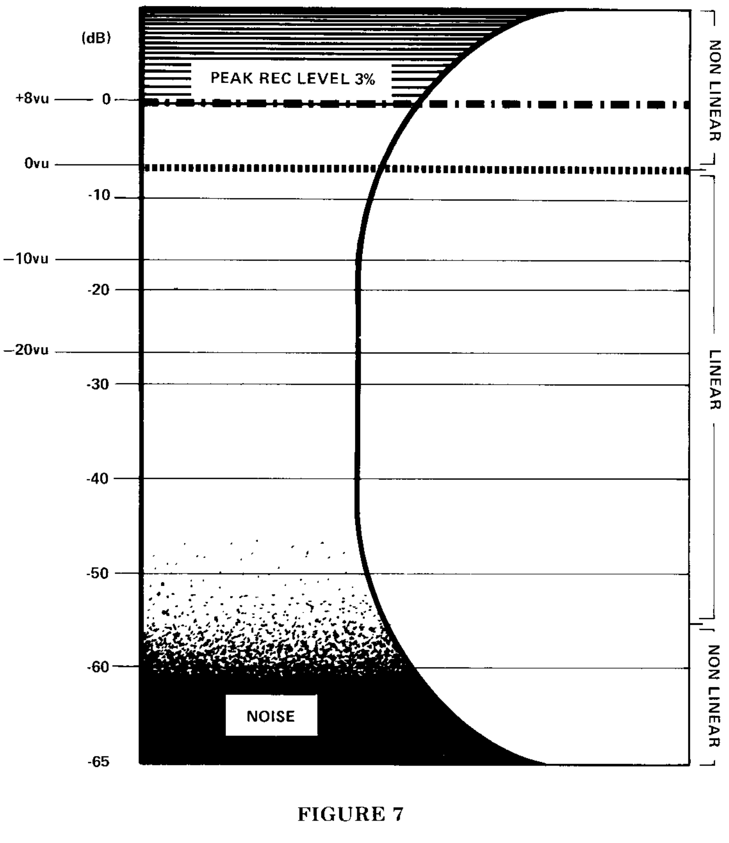


FIGURE 7

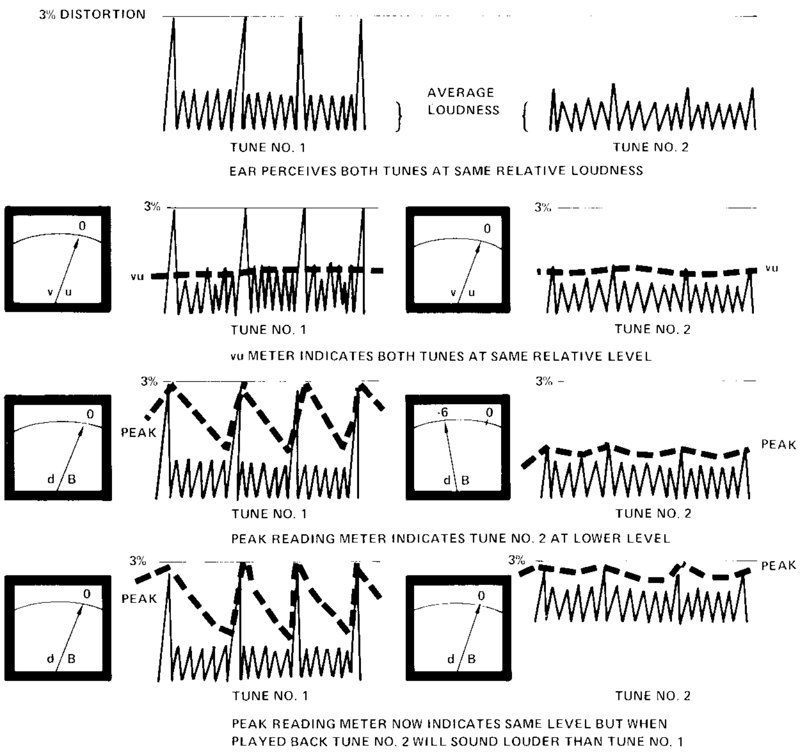

3% DISTORTION
AVERAGE LOUDNESS
TUNE NO. 1
TUNE NO. 2
EAR PERCEIVES BOTH TUNES AT SAME RELATIVE LOUDNESS
3%
0
v/u
vu
TUNE NO. 1
TUNE NO. 2
vu METER INDICATES BOTH TUNES AT SAME RELATIVE LEVEL
3%
PEAK
d/B
-6
TUNE NO. 1
TUNE NO. 2
PEAK READING METER INDICATES TUNE NO. 2 AT LOWER LEVEL
TUNE NO. 1
TUNE NO. 2
PEAK READING METER NOW INDICATES SAME LEVEL BUT WHEN PLAYED BACK TUNE NO. 2 WILL SOUND LOUDER THAN TUNE NO. 1

FIGURE 8

tions of a second. These sharp increases are called transients. Generally, these transients do not greatly affect the overall perceived average loudness of music (see Figure #8). However, these transients must be taken into account, for if they are strong enough, the recording will distort badly. Therefore, a metering system for recording was created that measures overall loudness — yet responds somewhat to peaks. This device is called a VU (volume unit) meter. The VU meter closely approximates the dynamic response of the human ear. Some peaks may be occurring above the meter indication, but because of the meter's design, it does not fully indicate them. Of course, even if they could be seen, it would be too late to do anything about it, for they would have already been recorded.

The VU meter is often adjusted so that it will allow peaks to occur 6-8 dB more than what the meter shows. Figure 7 shows that the "O" VU position on a VU meter will only cause the tape to record a 1,000 Hz tone at less than 1% distortion. To cause distortion to 3%, the level would have to be raised to 6-8 dB above "O" VU.

When using a VU meter, levels can be set so that the loudest passages do not go beyond "O" VU — indicating the level the human ear would perceive. If the music happens to contain some sharp transients, there is still sufficient "head room" before they could distort more than 3%. With this system, therefore, the user can set controls from tune to tune at the **same** level; and if some tunes contain higher peaks than what the meters indicate, no problems are created.

At speeds of 7½ or above, the user then wouldn't have to worry about high frequency roll-off. He wouldn't have to worry about transients distorting the recording. He would be able to professionally record each tune at the same overall level.

At slower speeds, particularly at 1-7/8 ips cassette speed and 3-3/4 ips, there isn't as much "head room". Tape distorts far more easily at these speeds. Therefore, these peaks or transients become more of a problem.

Another metering system was created as a hopeful remedy to this problem. It is called the "peak reading meter". The peak reading meter is driven by electronics that cause the meter to follow the actual transient peaks of music more closely. It is generally calibrated so that the "O" indication is very close to 3%. For this reason, it is also called a decibel or dB meter. It does read peaks, but because of its inherent design, it doesn't indicate overall level or accurately represent the dynamics of the human ear. Unfortunately, however, if different tunes with different transient characteristics are recorded one after another, the user wouldn't be aware of it and might unknowingly record the material at different overall levels.

We had to face this problem at TEAC. Many different proposals were made for the proper metering system to use on cassette recorders. The final version now used gives the recordist **both** metering systems — VU and peak. One set of electronics drives a VU meter to indicate overall level, and another set of electronics drives an LED (light emitting diode) to indicate peaks.

In this way, the user is given quite a lot of knowledge about the type of music he's recording. He knows what the overall loudness is compared to the peak levels. He might actually find that some music causes the LED to light when the VU meter is reading as low as -8 VU! This simply tells him that a particular tune has many loud peaks. In such a case, he would record at a level that would only cause the LED to light occasionally. If the next tune doesn't have as many loud peaks, he might raise the level on the VU meter to a higher point before the LED would again start to light. Here, the VU meter would tell him that he is recording louder than the previous tune — which means he is going to have a loudness difference from one tune to the next. In these instances, levels should probably be set by the VU meter for more professional recording results.

Remember: You cannot become a captive to meters. Use them as guides, not gods. Recording is an art which requires practice and the use of your judgment. Meters are only there to help make those critical judgments easier.

Equalization

All signals are not recreated equally.

A tape recorder does not reproduce signals linearly. In fact, the play head is anything but flat. As it detects a faster and faster magnetic field passing by it (from the tape) a larger and larger voltage is sent out of the head. As you can see by Figure #9, the voltage increases as the frequency increases.

Up to a point.

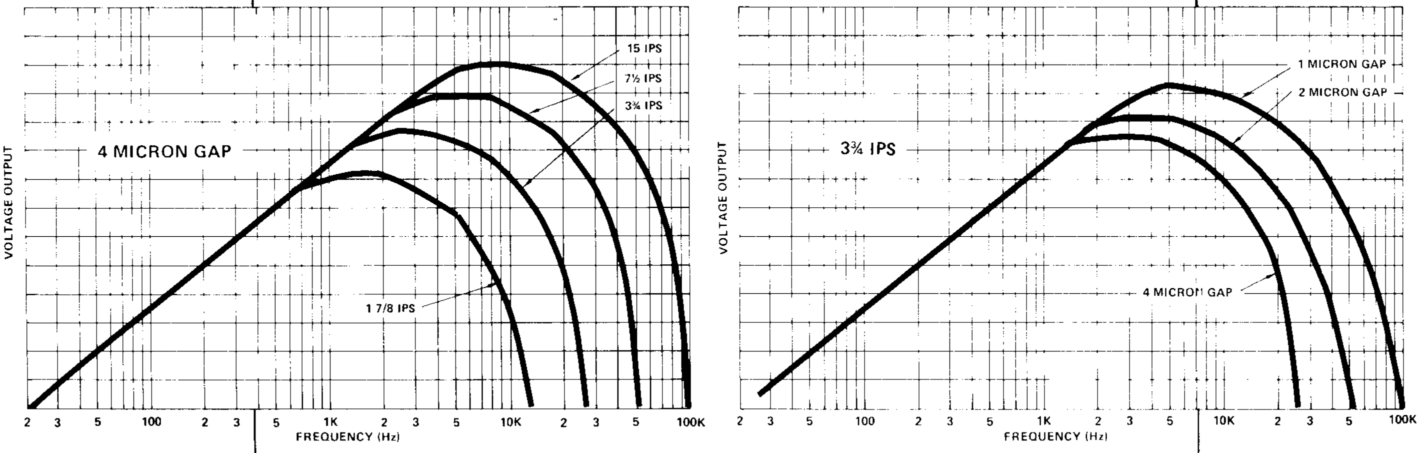


FIGURE 9

Sooner or later, the level drops off. Two factors cause this. When the wave length shortens and approaches the gap length, the level drops. And when the tape begins to saturate, the level drops. Obviously, the curve depicted here in Figure #9 would look different with different gap lengths and different tape speeds. But the principle is the same; the shorter the gap length, the further the curve extends. The faster the speed, the further the curve extends.

This curve would be completely unacceptable for audio reproduction. The process by which much of the high-frequency roll-off is restored is called equalization. The resulting curve should be as flat as possible, taking into account **all aspects of good fidelity.**

The objective of equalization is, insofar as possible, to reproduce all frequencies at their original volume level. For the purpose of illustration, let's consider high frequency equalization. A tape recorder designer has two chances to flatten the curve. In the record mode and again in the playback mode. Figure #9 shows output from the head rolling off after a few thousand Hz, depending on the speed and head gap length. Record equalization can boost this roll-off somewhat, but if too much boost is introduced here, the tape will saturate and high frequencies will again be lost. Play equalization will help, but if too much of **that** is used, there will be a marked increase in hiss. Therefore a curve, establishing a balance between the two equalizations, must be designed to minimize the problems inherent in each.

Philosophical decisions regarding the balance of record and play equalization may vary from manufacturer to manufacturer. However, several years ago, the professionals solved this problem by standardizing various curves at the different speeds. This, under the auspices of the National Association of Broadcasters (NAB). (see Figure #10)

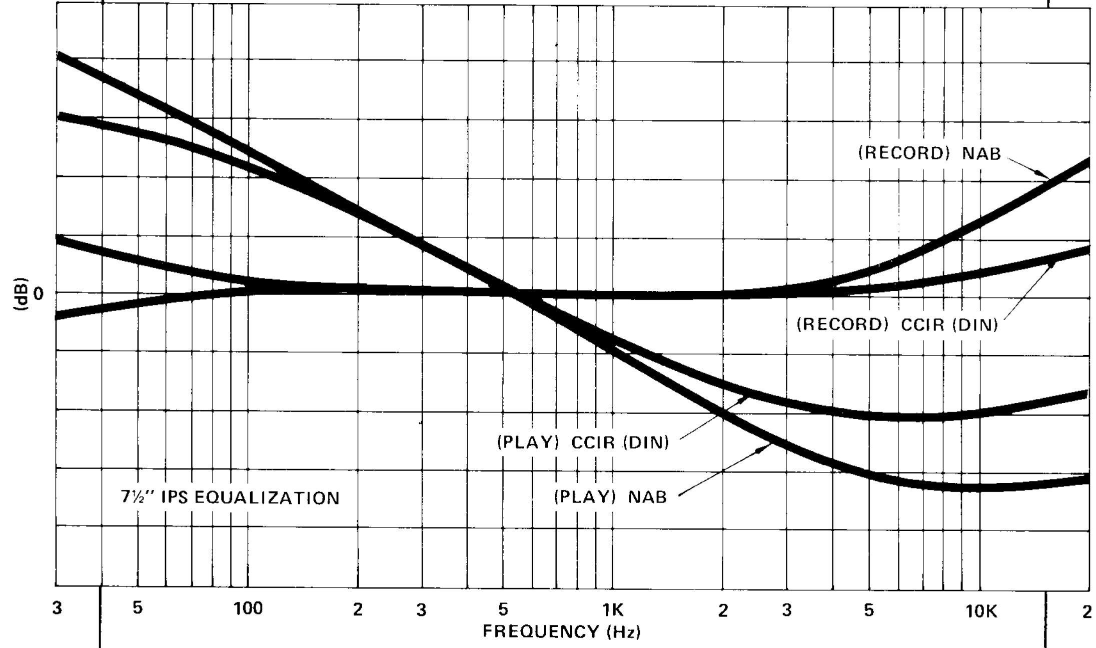


FIGURE 10

In establishing these parameters, the requirements of the professional recording engineer were paramount. His philosophy is to maximize or minimize — as the case may be — all fidelity parameters such as tape hiss, drop outs, distortion, "head room", etc. After all these were considered, only then was frequency response measured. If it did not meet professional standards, the music would be recorded at a faster speed. Remember: The faster the speed, the less equalization that is needed.

As the years went by, the tape recorder outgrew its "audiophile only" image and became a mass consumer item. At this point, slower speeds became popular because of convenience and economy. But the non-audiophile consumer, not certain as to how to read specification sheets, seized on a figure that was readily discernible and comprehensible; high frequency response. Thus, high frequency response was blown all out of proportion as a means of judging the efficacy of tape recorders.

As a result, certain manufacturers changed their curves in response to consumer interest. By using somewhat less record equalization, they extended the frequency response out a few more thousand Hz. However, they then had to increase play equalization. The result; increased high frequency hiss. Figure #10 shows the difference between the NAB and the European, CCIR or DIN, record and play equalization curves for 3-3/4 ips. TEAC has always designed recorders around the NAB philosophy. Therefore, our high frequency response, taken as a single factor, has generally never equalled those of manufacturers with different philosophies.

To illustrate this, we've reprinted here the frequency response specifications of a current state-of-the-art studio tape recorder. This machine uses 1/4″ tape at 15 ips, with two tracks – and it costs about $4,000. It is one of two brands most often used in studios. Specifications on the other are similar.

3-3/4 ips 30 Hz to 7500 Hz +1 -2 dB
7-1/2 ips 30 Hz to 15000 Hz +1 -2 dB

Isn't it just a bit incredible that most of the tape recorders available to consumers are purported to be better than the decks available to the professionals? Especially for the difference in cost?

However, thanks to new tape formulations that give increased high frequency response and thanks also to slight changes in the curves, TEAC can now deliver a high frequency response beyond 16,000 Hz at 3-3/4 ips measured at a level of -20 dB — and still provide all of the electronic and mechanical advantages for which some high frequency performance was originally traded. But we can do the same at -10 dB for 15 ips. That 10 dB signal-to-noise differential will exist for any manufacturer's product — irrespective of specification claims. Note that we **state** the level used to measure frequency response.

One reason then for making a specific tape recorder brand and/or speed decision would be the **level** at which high frequencies could be recorded without tape saturation. Obviously, faster speeds are "more forgiving" of the frequency level content of various types of music. They simply permit recording of higher volume levels of frequencies without fear of saturation. It's ironic, however, that the amateur recordist who generally knows the least about the art of recording is probably using the slower speeds where levels are far more critical. And the professional recording engineer, the person most knowledgeable in the art of recording, is using the faster speeds that are the most "forgiving" at critical levels.

Always use the fastest speed you can!

A few years ago, the industry introduced Chromium Dioxide (CrO_2) tape that delivered a high frequency bump above 10 KHz. It's interesting to note that tape recorder designers might have reduced the record equalization to extend response slightly. Instead, they choose to reduce play equalization and hence tape hiss. Nearly the entire tape recorder industry has adopted this form of equalization for CrO_2 tape — including European manufacturers, despite the fact that the curve is more NAB than DIN in philosophy.

Incidentally, different tape formulations require different record and/or play equalization. Therefore, switches are provided on most reel-to-reel and cassette units to adjust to various formulations. When a manufacturer specifies a particular tape to give his deck best overall performance, believe him!

Bias

Another adjustment on tape decks is bias switching. To understand bias, let's review the magnetic recording process described at the beginning of **The White Paper.** There we pointed out that the magnetic fields generated by the record head magnetize the oxide on the tape at various intensities and directions.

Now, when you send a signal into an amplifier, you want the shape of that signal to "look" the same on the tape as it did in the amplifier. Any variation would be **distortion** of the original. The magnetic pattern recorded on the tape should accurately relate to the magnetic fields generated by the record head. If we start with a particle with zero magnetism (as shown in Figure #11), we see that as magnetic field strength is **applied** to the particle (horizontal line), an equal amount of magnetic field strength should be **retained** by the particle (vertical line). Or, at least the relationship between increases and decreases of applied and retained magnetic fields should be proportional.

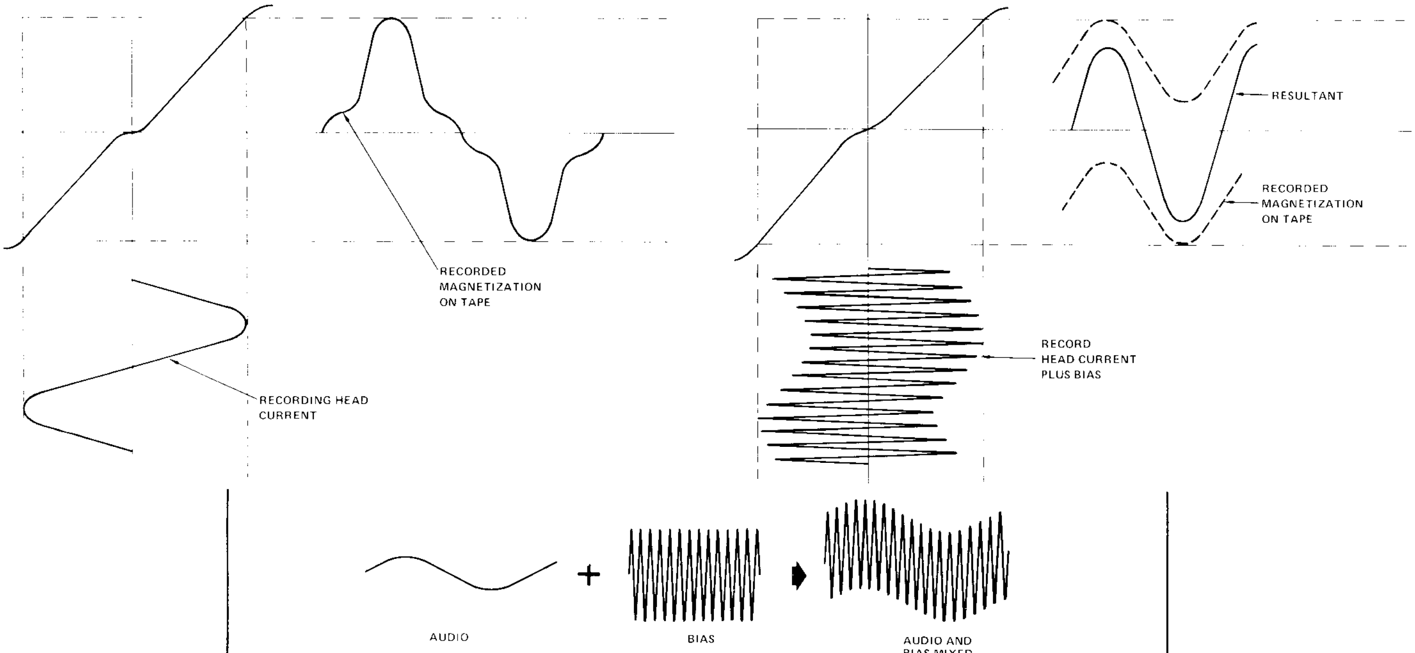

RECORDED MAGNETIZATION ON TAPE
RECORDING HEAD CURRENT
RESULTANT
RECORDED MAGNETIZATION ON TAPE
RECORD HEAD CURRENT PLUS BIAS
AUDIO
BIAS
AUDIO AND BIAS MIXED

FIGURE 11

Put another way, when an **applied** field doubles in strength, the **retained** field of the particle should also double in strength.

Unfortunately, oxide particles on the tape do not work this way over the entire range of retained magnetism. To begin with, there is a certain amount of "magnetic inertia" at the moment a particle starts to become magnetized. After this initial resistance, the particle then reacts "correctly" and linearly to the applied field. This continues as the applied signal becomes stronger and stronger, until the particle reaches its maximum strength. Somehow then, we must only apply the audio signal's magnetic field to that part of the oxide's curve that is linear. If we don't, the recorded signal would look like the signal at the left of Figure #11.

The solution is to "prepare" the particle to receive the entire audio magnetic spectrum "correctly". This is accomplished by sending a super high frequency signal, generally over 100,000 Hz into the record head. This **bias** signal generates a magnetic field that magnetizes the particles through the non-linear segment of the curve. Then, the audio signal is applied, **on top** of this bias signal. The bias signal causes the audio signal to change the **relative** magnetization of the particles, and reduces audible distortion. The bias is, of course, recording a series of magnetic fields of its own. But they are so short that the playback head can't retrieve them (see Figure #11).

There are different types of oxide particles. Different lengths. Different materials. Each requires different bias strength. That's why most tape recorders have bias switches to match the varying bias requirements of tapes.

In short, a bias signal is applied along with the audio signal to minimize tape distortion during the recording process. On the other hand, if too **much** bias is applied, extreme high frequencies will be suppressed. But a **slight** amount of excess bias is beneficial: It can reduce the amount of recording dropouts that occur because of problems caused by the physical surfaces of the tape itself, e.g. poor dispersion of particles. In the past, it was general practice in professional situations to slightly over-bias even though it did result in minimal high frequency loss. But remember, the professional recording engineer never sacrifices other performance parameters merely to achieve extended frequency response.

Signal - To - Noise Ratio

Another area of confusion is the specification on signal-to-noise ratios. There are so many different methods of rating this particular area of performance that the numbers become meaningless when comparing one manufacturer with another.

Signal-to-noise specifications are designed to give the deck's performance in relationship to the maximum signal that can be recorded without exceeding a given distortion point, when compared to the inherent noise that is generated by the recorder's electronics and tape. The problem is; what is meant by maximum signal? And what kind of noise is being measured?

One step at a time — first, maximum signal. One method is to record a 400-1,000 Hz tone on a tape until the distortion off the play head reaches 3%. This becomes the maximum signal that can be recorded. This distortion level will vary from tape to tape. If a recorder manufacturer utilizes VU meters he might choose to calibrate the meters to read around 1% distortion at "O" VU and allow peaks to reach +6VU before 3% distortion would occur. (see Figure #7). Putting on another brand of tape might still read around 1% at "O" VU but would not read 3% until maybe +9VU. This last condition would allow recording at +3VU and still leave 6 dB head-room for possible high transients.

If the recordist decides that he will always use this better tape, he could have a service man recalibrate the meter for this tape. When a signal-to-noise ratio is given it is always in relation to a particular blank tape; find out what tape it is. Often two different recorder manufacturers will specify their signal-to-noise ratio with different tapes and the specifications will be different because of the tape difference. We are now adjusting our recorders for the new generation of tapes, and that in itself has given us a 3 dB improvement in signal-to-noise.

If one measures signal-to-noise at the "O" point on a meter then the measurement depends on the metering system and calibration philosophy of that particular manufacturer (see section on meters). If a meter is calibrated to 3% at its "O" point then its signal-to-noise will be anywhere from 6 to 9 dB or better on paper than a meter which has its "O" point at 1% distortion. The argument for measuring at the "O" point is that the owner sets either type of meter at the "O" point for maximum levels, so therefore the signal-to-noise should be measured there!

Unfortunately, this argument fails to take into account the fact that the "O" point meter at 3% is probably also an equalized meter and the only time the signal-to-noise ratio is that particular number is at 1,000 Hz! As the frequency gets higher than 1,000 Hz at the same level the effective signal-to-noise goes down.

The other point is that the "O" point at 3% then means that the user will always be setting the music to peak out at 3%. The meter that is not equalized and only reads 1% at its "O" point **may** have music that has transients to 3% **depending on the music.**

As you can see, the myriad of metering philosophies prevalent today end up negating any standard method for measuring signal-to-noise. A system that would relate signal-to-noise under all musical conditions has yet to be devised.

The second issue in signal-to-noise ratio is: noise. What is noise? Tape recorder noise only? Tape noise only? Both? Unweighted noise? Weighted noise?

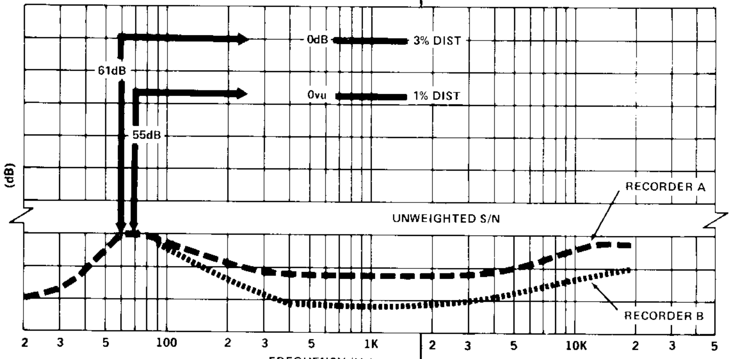


FIGURE 12

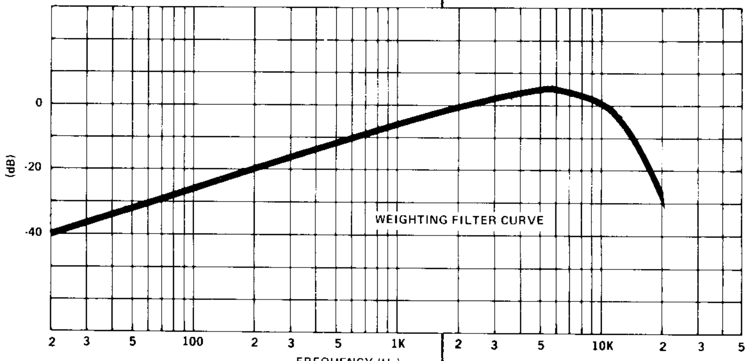


FIGURE 13

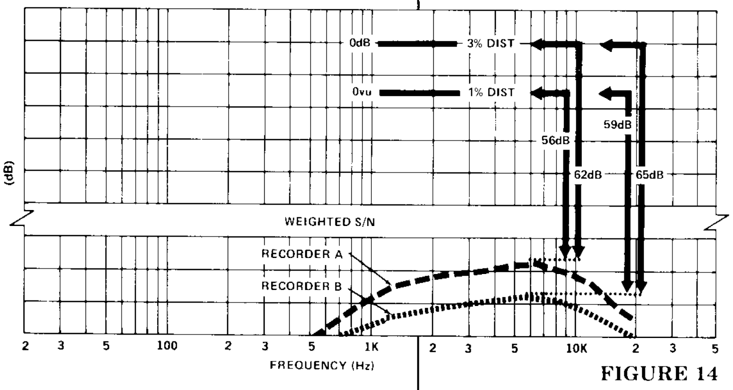


FIGURE 14

The first consideration is this: Tape recorder noise does not occur at the same volume level across the entire frequency spectrum. Low frequency noise (hum) is generally louder than high frequency noise (hiss). However, the human ear does not perceive noise in that relationship. We hear mid-range sounds as being loudest, even though all frequencies might be at equal levels if measured electronically. You can see by Figure #12 that recorder "A" has more hiss than recorder "B". But the unweighted signal-to-noise will show to be at the same noise level (61 dB at 3% distortion).

There have been many suggestions as to what the correct weighted curve should be. Each curve attempts to simulate human ear characteristics. An example is shown here (see Figure #13). All have one thing in common. That is the desire to give a signal-to-noise measurement more credibility, by giving more accurate indication of what the ear is telling the listener.

We now send the overall noise through this weighted filter and then measure the noise that remains (see Figure #14). The measurements of recorder "A" emerge at 62 dB and those of tape recorder

"B" at 65 dB at 3% distortion. Now, the signal-to-noise specification offers a number that more accurately corresponds to what the listener actually hears.

The tape recorder industry should adopt a standard, uniform weighting curve. In the near future, all TEAC specification sheets will show weighted — as well as unweighted — signal-to-noise specifications shown at both "O" VU and 3% distortion. However, this program will take time to implement. Until it is, you can assume that any TEAC signal-to-noise specification that does not state full test parameters is measured unweighted at "O" VU. Bear in mind, however, that signal-to-noise specifications on other brands may not be derived the same way. Therefore, you should ascertain the test method used before making specification comparisons.

Transport Mechanics

A convincing case could be made to demonstrate that quality of transport mechanism is the single most important consideration in choosing a tape recorder today.

Consider the reasons: State-of-the-art in today's electronics is close to state-of-hearing in the human ear. High quality electronic parts are getting relatively less expensive all the time; their reliability factor is good and getting better. Moreover, this advanced electronics technology is available to most manufacturers if they are willing to pay for it. And, as stated before, there are essentially no "secrets" in the tape recorder industry. The same technology is available to every manufacturer.

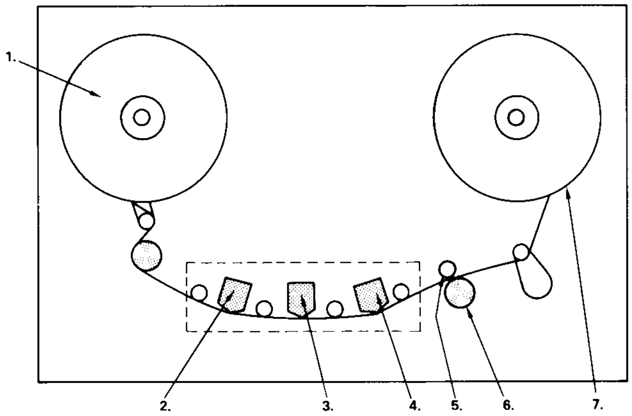
What, then, makes for good transport construction? Basically, design philosophy and experience. Lots of experience.

An analogy can be made to construction of a violin. Given the same plans, specifications, and even wood, two different individuals could construct two different instruments. Yes, they would both look alike, have the same configuration, same number of strings, etc. But one would end up a squeaky fiddle and the other a fine concert instrument. The difference: design philosophy and experience.

The construction of a tape transport requires as much art as science. You'll see why as we further discuss transport mechanics.

A transport does three things (see Figure #15). First, it holds the tape to be played on a supply reel. Second, it pulls the tape off the supply reel and past the erase, record and play heads by means of a capstan and pinch-roller. Third, it then stores the tape by means of a take-up reel.

DESIGNATION OF TAPE TRANSPORT COMPONENTS



1. LEFT REEL (SUPPLY REEL)
2. ERASE HEAD
3. RECORD HEAD
4. PLAYBACK HEAD
5. CAPSTAN
6. PRESSURE ROLLER (PINCH ROLLER)
7. RIGHT REEL (TAKEUP REEL)

FIGURE 15

The Capstan/Pinch - Roller Assembly

Let's look at the capstan/pinch-roller assembly first (see Figure #16). The capstan turns at a steady speed. As it turns, the capstan pulls the tape which is pressed tightly against it by the pinch-roller. Roundness of the capstan shaft is ultra-critical, for if it is not so, the tape will be pulled unsteadily. This will cause an audible change in pitch of the musical material, called "wow and flutter". Generally speaking, the larger the capstan diameters, the lower wow and flutter, because the same tolerance of roundness will not be as critical in larger diameter shafts.

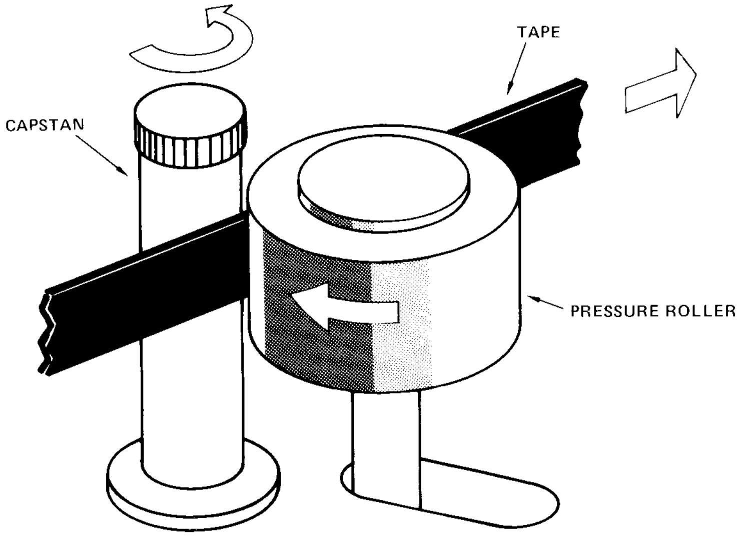


FIGURE 16

Motors

How is the capstan rotated? Obviously, it all begins with a motor.

And, several possible types of motors may be used. The most basic (and inexpensive) is the standard 2 or 4 pole motor. Its speed is governed by the voltage applied to it. The problem is that in ordinary household situations, voltage can fluctuate significantly enough to cause noticeable changes in pitch. To avoid this, speed consistency is critical. For this reason, a standard 2 or 4 pole induction motor is not acceptable for quality tape recorders, and we don't use them.

Another type of motor is the hysteresis synchronous. These generally use 4 or 8 poles. The hysteresis synchronous motor derives its speed from the 60 Hz frequency of normal U.S. household current. It can operate over a large voltage range (90-130) without speed fluctuations. Hence, it is suitable for quality tape recorder use. We use hysteresis synchronous motors on certain transports — but with a difference. The motor is an outer-rotor configuration. Here, the heavier rotating part of the motor is on the outside, instead of its normal inside position. This "fly wheel" effect adds more inertial stability to the motor for even lower wow and flutter.

Another type is the servo-controlled motor. It governs its speed through a feed-back circuit that measures motor rotation and adjusts for minor speed fluctuations. This holds the rotation absolutely steady.

The servo-controlled motor can out-perform the hysteresis synchronous in both speed stability and low wow and flutter characteristics. But the mere fact that a tape recorder has a servo motor does not in itself guarantee that final total recorder performance will be better or even as good. Other factors, such as cost of the motor itself and mechanical parameters, should be taken into consideration. The end result is what counts.

Our more costly reel-to-reel products utilize servo motors. They deliver incredibly good wow and flutter specifications. For example, there is a servo-controlled motor that utilizes the motor shaft as the capstan shaft itself. This eliminates all linkages and belts, improves efficiency and reduces wow and flutter even further (see Figure #17).

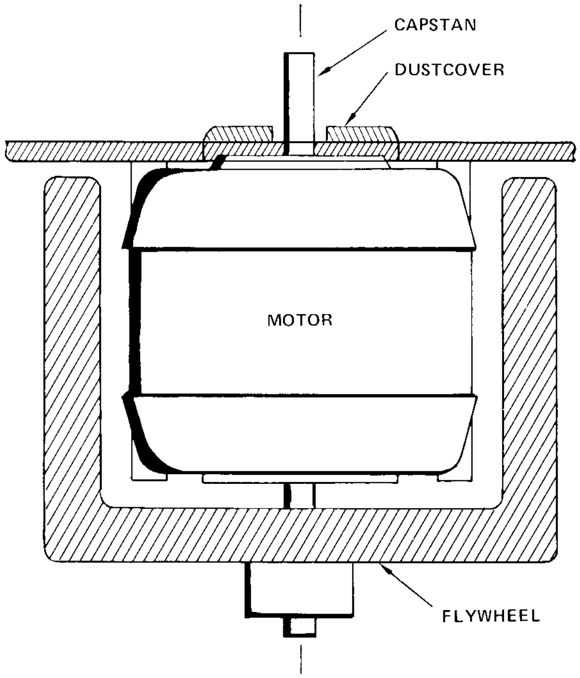


FIGURE 17

Capstan/Motor Hook-Up

The typical motor drives the capstan by either idler wheel linkage or belt (see Figure #18). The idler wheel linkage has the advantage of making easier speed changes. The linkage simply raises the idler wheel up or down and brings it into contact with

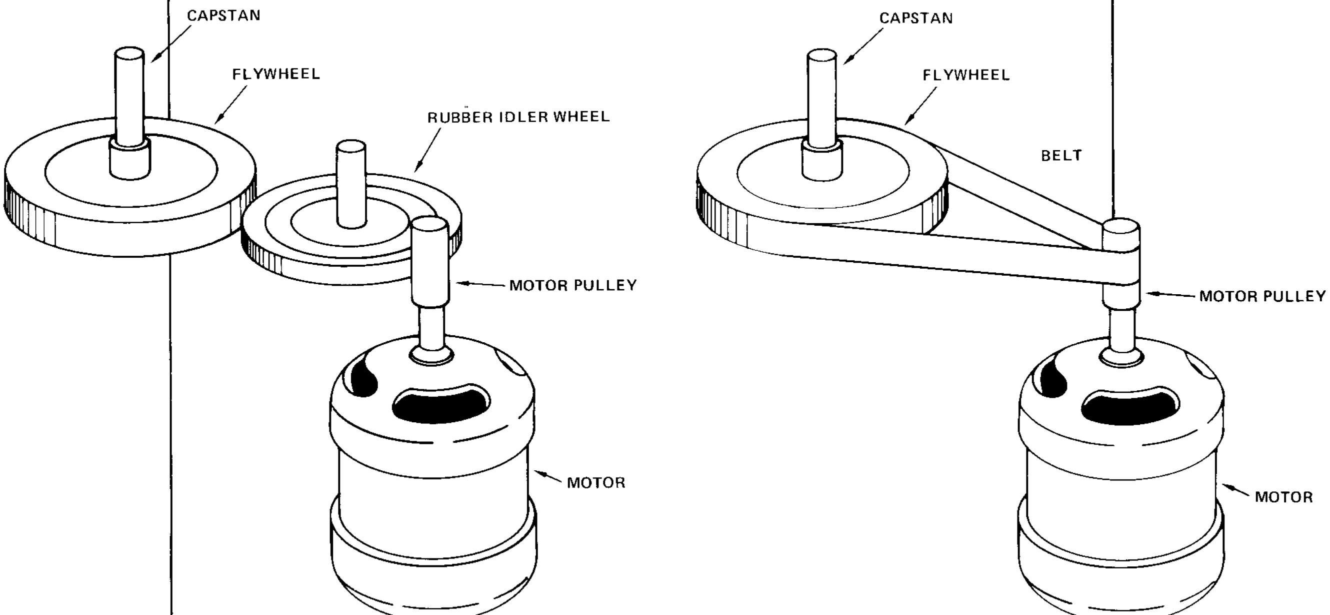


FIGURE 18

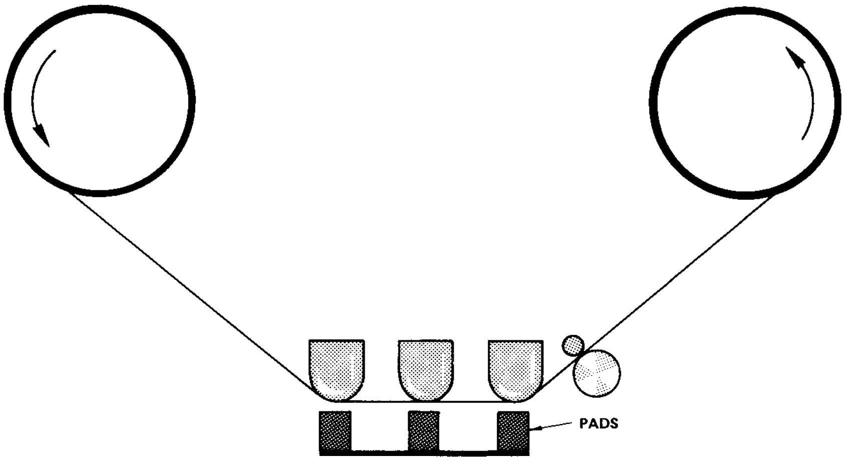
a pulley on the motor that has three or more different diameters — one diameter for each speed. The disadvantage of idler wheel linkage is that the rubber covers on the outer rim of the idler wheels eventually become hard, transmitting motor vibration directly to the capstan. Wow and flutter goes up greatly as the recorder is used.

While the belt drive capstan does not have this vibration problem, it cannot move up and down to different pulley diameters to change speeds as easily as can the idler wheel system. The belt system uses a change in the motor speed itself. We use this system. It means that we only provide two speed options rather than three, but performance is more stable and reliable over the years.

What then drives the take up and supply reels? Often, the same motor that drives the capstan. They are all hooked together by idler wheel linkages and slip-clutches, but not in a TEAC.

Tape - To - Head Contact

To achieve good recording and playback, the tape must have intimate contact with the head. The method that provides the best contact available is the pressure pad system (see Figure #19). This is accomplished by pushing the tape directly against the head with small felt pads. Pressure pads are virtually mandatory in cassettes, where the slightest movement away from the head would have disastrous effects on high frequency response. But, at higher tape speeds, such as 7½ and 15 ips, pressure pads create problems such as head wear, tape edge stretch and high frequency flutter.



1 MOTOR TRANSPORT WITH PRESSURE PADS

FIGURE 19

An alternative is the capstan/supply reel tension system. Here the tape is stretched taut between capstan and supply reel. This causes the tape to wrap around the face of the heads. But tension must be just right, because too much will cause tape stretch and too little will cause high frequency loss.

However, tension can only come when tape is pulled in both directions simultaneously. A mechanism is needed to create back tension. Often employed is a slip clutch under the supply reel. This device causes a slight drag on the reel.

Unfortunately, most slip clutches do not drag at a constant rate over a period of time. Uneven tension can then cause flutter problems and high frequency drop-outs. We don't use this system.

Another back torque mechanism is a second capstan on the left side of the heads (see Figure #20). Generally, one motor drives both forward and back capstans, using a belt that goes around both capstans. By creating a differential drive between

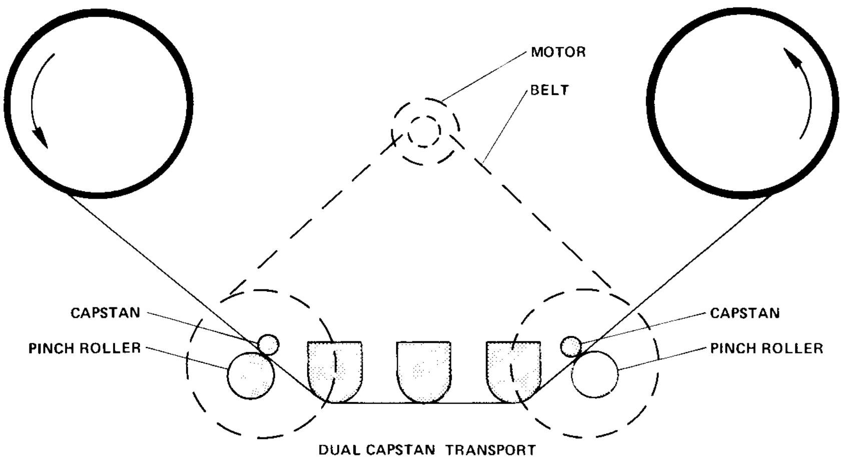


FIGURE 20

the two capstans, the trailing capstan (to the left of the heads) rotates slightly more slowly than the leading capstan. This puts the tape between the two capstans under tension, causing it to wrap around the heads for good contact.

But the dual-capstan system can introduce as many problems as it solves. The balance is very delicate, and the two capstans can easily get out of sync. For instance, if the two capstans rotate at exactly the same speed there will be no tension. As a result, the tape will lose tight head contact, resulting in high frequency response drop-outs. On the other hand, if the capstans are out of sync the other way, there will be too much tension on the tape. At this point, the entire system begins to "fight itself". When this happens wow and flutter goes up tremendously.

We use the dual capstan system, but with care.

The back-tension solution on professional reel-to-reel recorders is a separate motor under the supply reel (see Figure #21). This

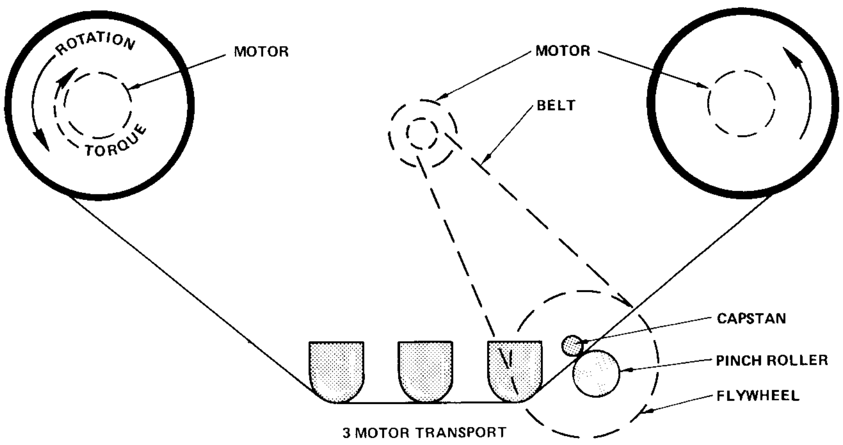


FIGURE 21

motor receives a small amount of voltage, which causes it to attempt rotation in the opposite direction of tape travel. This creates the slight amount of uniform tension needed for good tape-head contact. We use this system, in **all** our open reel recorders, even though it requires three motors, and adds significantly to cost — it's worth it.

Once again, the issue is overall performance and reliability. When designing a transport, the quality of all the components has to be properly balanced with the desired outcome. There is no sense in putting an expensive low wow and flutter motor into a transport with poorly constructed pulleys and bearings that create the same wow and flutter you tried to get rid of with the expensive motor. Proper balance of components at a particular price point is the key to maximum performance for dollar investment.

Cassette Mechanics

In various sections of **The White Paper,** we have called attention to the special problems inherent in the cassette configuration. But by far the most significant weakness in cassettes from a mechanical standpoint is the cassette tape case itself - not the recorder.

For instance, the issue of tape spill still plagues the industry. In reel-to-reel transports, the tape and the plastic reel turn together. In a cassette, however, the tape turns — but the plastic case remains stationary. As a result, no matter how good a cassette transport you own, the entire cassette — the case, reels and tape — becomes part of your transport system. That's always a potential problem because there is invariably friction between the stationary plastic case and the rotating reel of tape. That friction can be reduced by introducing a spacer washer between them — coated with a slick substance like graphite or Teflon – to reduce friction. At present state-of-the-art, however, friction cannot be totally eliminated.

Cassette designers anticipate a certain amount of friction and adjust hold-back and take-up torques to compensate for it. "Ideal" take-up torque is delivered when there is just enough torque to rotate the take-up reel and overcome any anticipated friction. Too much take-up torque jerks the tape past the capstan causing a large increase in wow and flutter.

Remember, a big motor is not the key to "ideal" take-up torque. No matter what the motor size, there is still only one "ideal" amount of take-up torque. And if the cassette itself doesn't meet its ideal torque requirements, no motor in the world will be able to correct it. Many well-constructed cassettes are on the market today as well as some poor ones.

An easy way to judge mechanical quality construction of a cassette tape is to put the tape in a deck, place the deck in a play mode and put your ear close. Listen for mechanical noises, like rubbing or grinding. A good cassette generates little noise. Any noise you hear results from poor construction of the cassette. Another test of quality is to put the deck in fast rewind mode and listen to the cassette. A badly constructed cassette cartridge will rattle severely.

Transport Controls

The easiest, least expensive way to activate the various mechanical linkages of a tape recorder is through direct, manual operation. To go into play mode, you push down a button or lever. Or you twist a knob. This pulls the pinch-roller up against the capstan, releases the reel brakes, activates the take-up reel, and in general, gets things going. However, long term reliability is questionable and we don't use this system on reel-to-reel decks.

The other means of transport control is solenoid activation. The solenoid itself is controlled by a direct coupled switch on the front control panel. Generally, a minimum of three solenoids are required to operate a transport. One each for the pinch-roller, supply reel brakes, and take-up reel brakes. More can be used if other functions like "pause" or "record" would require mechanical linkages and switches.

Even more sophisticated transports use solid-state switching. Here, a "feather-light" touch micro-switch push button activates the solenoids. TEAC uses solid-state switching, together with new integrated circuits (ICs), on its more sophisticated transports, balanced with equal sophistication — in performance, features and versatility. Our **entire** reel-to-reel line has three motors and micro-switch, solenoid operated transport systems.

As cassettes continue to increase in performance and versatility, you'll find some top-of-the-line decks also employing solenoid transport controls. We must not forget, however, that this expense can only be justified when other features are also state-of-the-art, like low wow and flutter and optimum frequency response. For instance, some expensive cassette decks use solenoid transport controls but still have mediocre wow and flutter specifications of around 0.15 to 0.25%. That much wow and flutter is acceptable in a low cost deck, where economy is a big selling feature. But to add expensive solenoids to a unit at the sacrifice of performance is, from our point of view, a disservice to the purchaser. Sophisticated cosmetics give him the wrong impression of the deck's performance.

It comes back again to that same word — balance. All features should be integrated with performance in all price categories. That is the only way the final product will end up being the best possible value for the money spent.